

# MACHINE DESIGN

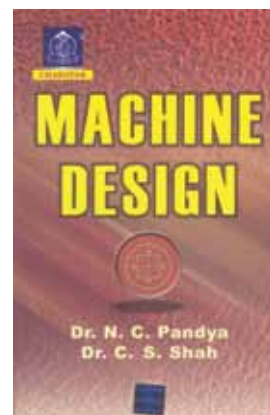
[ ENTIRELY IN SI UNITS ]

By  
Dr. N. C. Pandya & Dr. C. S. Shah

**Edition** : 17<sup>th</sup> Edition : 2009  
**ISBN** : 978 - 81 - 85594-92 - 7  
**Size** : 135 mm × 210 mm  
**Binding** : Paperback with Four color Jacket Cover  
**Pages** : 1064 + 16



CHAROTAR



₹ 240.00

## ABOUT THE BOOK

This text-book aims at presenting the fundamental principles of Mechanical Engineering Design or Design of Machine Elements.

The fundamentals of theory and design are presented as lucidly as possible to enable the students in engineering institutions to get a clear grasp of the basic principles of the subject.

It explains the general theory of mechanical engineering design and sets out problems for the students aimed at equipping them for design of machine parts with intelligence and understanding.

Throughout this book the chief aim has been to illustrate the subject matter fully with suitable diagrams and by direct treatment of the subject matter.

The book contains numerous examples carefully chosen from past examination papers of various Indian Universities.

The book is intended for Mechanical Engineering students preparing for degree examinations in engineering of almost all the Indian Universities, Diploma Examinations of various Technical Boards, certificate courses, examinations of A.M.I.E., U.P.S.C., G.A.T.E., I.E.S. and other similar competitive and professional examinations. It should also prove of great interest and practical use to the practising engineers.

## CONTENT

- 1 : MATERIALS OF CONSTRUCTION AND THEIR PROPERTIES
- 2 : DESIGN CONSIDERATIONS IN MACHINE PARTS
- 3 : CYLINDERS, TANKS AND PIPES
- 4 : RIVETED JOINTS
- 5 : BOLTS, NUTS AND SCREWS
- 6 : COTTER AND KNUCKLE JOINTS
- 7 : SHAFTS, KEYS AND COUPLINGS
- 8 : SPRINGS
- 9 : BEARINGS
- 10 : STRUTS AND COLUMNS
- 11 : POWER SCREWS
- 12 : LEVERS
- 13 : BRACKETS
- 14 : BELTS, PULLEYS AND CHAIN DRIVES
- 15 : FLYWHEELS
- 16 : GEARS
- 17 : WELDED CONNECTIONS
- 18 : DESIGN OF MISCELLANEOUS MACHINE PARTS I ENGINES AND BOILERS
- 19 : DESIGN OF MISCELLANEOUS MACHINE PARTS II BRAKES AND CLUTCHES
- 20 : DESIGN PROJECTS APPENDICES  
APPENDIX I TO APPENDIX XVII

Checklist

## Chapter 1 : MATERIALS OF CONSTRUCTION AND THEIR PROPERTIES

- 1-1 Introduction
- 1-2 Choice of material
  - Factors Affecting the choice of a Material
- 1-3 Materials of construction
  - (a) Ferrous Metals
  - (b) Non-ferrous Metals
- 1-4 Structure of materials
  - Structure of Metallic Materials
- 1-5 Mechanical properties of materials of construction
- 1-6 Determination of mechanical properties
- 1-7 Fabrication characteristics and processes of fabrication
  - (a) Formability Hot working processes, Cold working process  
Power metallurgy
  - (b) Castability, Solidification Rate, Shrinkage, Segregation  
Gas Porosity, Hot Strength
  - (c) Machinability
  - (d) Weldability, Heat and cooling, Oxidation Gas
- 1-8 Ferrous metals - Cast iron, wrought iron and steel
- 1-10 Available sizes
- 1-11 Accuracy
- 1-12 Finishing processes
- 1-13 Non-metallic materials
- 1-14 Plastics
- 1-15 Composite Materials
- 1-16 Improvements in properties of materials
  - Examples

## Chapter 2 : DESIGN CONSIDERATIONS IN MACHINE PARTS

- 2-1 Loads
- 2-2 Stress
- 2-3 Strain
- 2-4 Stress-Strain diagram : Modulus of elasticity
- 2-5 Poisson's ratio
- 2-6 Modulus of rigidity
- 2-7 Bulk modulus
- 2-8 Basic requirements of machine elements
  - (i) Strength
  - (ii) Stiffness
  - (iii) Wear resistance
- 2-9 Factor of safety : Selection of allowable stresses
- 2-10 Procedure for designing a machine element
- 2-11 Tensile stress
- 2-12 Compressive stress
- 2-13 Shearing stress
- 2-14 Bearing pressure intensity
- 2-15 Bending (Flexure) Effect or ribs on castings
- 2-16 Shear stresses in a beam
- 2-17 Torsion
- 2-18 Eccentric loading
- 2-19 Combined stresses : Bending combined with direct load
- 2-20 Offset connecting links and C shaped frames
- 2-21 Shear stresses combined with tensile and compressive stresses
- 2-22 Theories of elastic failure
- 2-23 Designing for impact loads
- 2-24 Design of members subjected to impact torsion
- 2-25 Stress concentration
- 2-26 Notch sensitivity
- 2-27 Effect of repeated application of a load
- 2-28 Fluctuating stress for ductile materials Ellipse quadrant relationship  
Design to avoid fatigue failure
- 2-29 Cumulative damage in fatigue : (Miner's equation)
- 2-30 Fatigue life determined by short-term testing
- 2-31 Light weight and minimum dimensions
- 2-32 Elastic matching
- 2-33 Temperature stresses
  - Examples

## Chapter 3 : CYLINDERS, TANKS AND PIPES

- 3-1 Introduction
- 3-2 Types of vessels
- 3-3 Design of thin cylinders
- 3-4 Design of a thin spherical shell
- 3-5 Cylindrical shell with hemi-spherical ends Cylindrical shell  
Hemispherical shell, Hemispherical shell
- 3-6 General theory of membrane stresses in vessels under internal pressure
- 3-7 Design of pipes
- 3-8 Design of thick cylinders, Design of hydraulic cylinder  
Other design considerations
- 3-9 Design equation for thick cylinders  
Examples

## Chapter 4 : RIVETED JOINTS

- 4-1 Introduction
- 4-2 Rivets
- 4-3 Rivet heads
- 4-4 Types of riveted joints
- 4-5 Caulking and fulling
- 4-6 Design of a riveted joint for boiler construction  
Design of a boiler joint
- 4-7 Efficiency of a riveted joint  
Design of a circumferential lap joint
- 4-8 Joints for storage tanks
- 4-9 Lozenge joint
- 4-10 Eccentric loads on riveted connections
- 4-11 Rules in designing riveted joints
- 4-12 Advantages of welding over riveting, Circular arrangement  
Rectangular arrangement, Triangular arrangement  
Examples

## Chapter 5 : BOLTS, NUTS AND SCREWS

- 5-1 Introduction
- 5-2 Definitions
- 5-3 Forms of screw threads
- 5-4 Advantages of square threads over V threads
- 5-5 Screw fastenings
  - (i) Through bolts
  - (ii) Tap bolts and cap screws
  - (iii) Machine screws
  - (iv) Set Screws
  - (v) Studs
- 5-6 Locking devices for nuts
- 5-7 Washers
- 5-8 Eye bolt
- 5-9 Efficiency of threads
- 5-10 Stresses in screw fastenings
- 5-11 Initial stresses
- 5-12 Stresses due to external forces
- 5-13 Stresses due to combined load
- 5-14 Bolts of uniform strength
- 5-15 Screwed boiler stays
- 5-16 Bolts subjected to shear
- 5-17 Bolts under eccentric loading
  - (a) When load is parallel to the bolt axis
    - (i) Rectangular base
    - (ii) Circular base
  - (b) When load is perpendicular to the axis of the bolt
- 5-18 Design of a nut
- 5-19 Power transmitting capacity of set screws  
Examples

**Chapter 6 : COTTER AND KNUCKLE JOINTS**

- 6-1 Introduction
- 6-2 Design of cottered joints
  - (a) Tension failure of the rods at diameter  $d$
  - (b) Tension failure of the rod across slot
  - (c) Tension failure of the socket across the slot
  - (d) Shear failure of the cotter
  - (e) Shear failure of the rod end
  - (g) Crushing failure of the rod or the cotter
  - (h) Crushing failure of the socket or the cotter
- 6-3 Gib and cotter
- 6-4 Connection of a piston rod to a crosshead
- 6-5 Cotter foundation bolts
- 6-6 Introduction
- 6-7 Joint of suspension links
- 6-8 Design of a coupler or a turnbuckle
  - (a) Diameter of the rod
  - (b) Length of the screwed portion of the nut at each end
  - (c) Outside diameter of the coupler at the nut portion
  - (d) Outside diameter of the coupler at the middle
- Examples

**Chapter 7 : SHAFTS, KEYS AND COUPLINGS**

- 7-1 Introduction
- 7-2 Materials and design stresses
- 7-3 Design of axles
- 7-4 Design of shafts on the basis of strength
  - (a) The maximum normal stress theory (Rankine's theory)
  - (b) The maximum shear stress theory (Guest's theory)
  - (c) The maximum strain theory (St. Venant's theory)
- Empirical design of shafts
- 7-5 Design of shafts on the basis of rigidity
  - Torsional, Lateral rigidity, Critical speed
- 7-6 Design of hollow and non-circular shafts
- 7-7 Form of keys
- 7-8 Keys
- 7-9 Design of sunk keys
- 7-10 Effect of keyways in sunk keys
- 7-11 Taper pins
- 7-12 Feather keys and splined shafts
- 7-13 Force and shrink fits (Driving fits on solid shafts)
- 7-14 Couplings : Introduction
- 7-15 Sleeve couplings or muff couplings
- 7-16 Clamp or compression couplings
- 7-17 Flange couplings
- 7-18 Marine type of flange couplings
- 7-19 Flexible couplings
- 7-20 Bushed pin type of flexible couplings
- 7-21 Bibby type of flexible coupling
- 7-22 Leather pad type flexible coupling
- 7-23 Oldham's coupling
- 7-24 Universal coupling
- 7-25 Safety couplings
- 7-26 Flexible shafts
- Examples

**Chapter 8 : SPRINGS**

- 8-1 Introduction
- 8-3 Optimum design of helical springs
- 8-4 Helical springs of non-circular wires
- 8-5 Concentric helical springs
- 8-6 General considerations in design of compression and extension springs
- 8-7 Torsion helical springs
- 8-8 Spiral springs (Power springs)
- 8-9 Leaf springs
- 8-10 Belleville springs
- 8-11 Energy-storage capacity
- Examples

**Chapter 9 : BEARINGS**

- 9-1 Introduction
- 9-2 Bearing area
- 9-3 Sliding bearings : Solid journal bearings
- 9-4 Divided journal bearing : Plummer block
- 9-5 Hydrodynamic theory of lubrication
- 9-6 Oil grooving
- 9-7 Heating of bearings
- 9-8 Design procedure for hydrodynamic journal bearings
- 9-9 Bearing materials
- 9-10 Design of bearing caps and bolts
- 9-11 Foot step or pivot bearings
- 9-12 Collar bearings
- 9-13 Anti-friction bearings
- 9-14 Radial ball bearings
- 9-15 Roller bearings
- 9-16 Selection of ball and roller bearings
- 9-17 Bearing load
  - (a) Calculations of a bearing load in gear drives
  - (b) Calculations of a bearing load in belt drives
- 9-18 Equivalent bearing load
  - (a) Combined bearing load
  - (b) Design for variable loading
- 9-19 Carrying capacity and life
- 9-20 Relationship between load and life
- 9-21 Requisite bearing life for different types of machines
- 9-22 Life or Timken bearings
- 9-23 Influence of high temperatures on load carrying capacity
- 9-24 Permissible misalignment
- 9-25 Friction in rolling bearings
- 9-26 Comparison of sleeve and rolling bearings
- Examples

**Chapter 10 : STRUTS AND COLUMNS**

- 10-1 Introduction
- 10-2 Euler's formula
- 10-3 End fixity coefficients
- 10-4 Radius of gyration and plane of buckling
- 10-5 Rankine's formula
- 10-6 Tetmajer's formula
- 10-7 Johnson formula
- 10-8 Design of push rods
- 10-9 Eccentrically loaded columns
- Examples

**Chapter 11 : POWER SCREWS**

- 11-1 Introduction
- 11-2 Forms of threads
- 11-3 Force analysis
- 11-4 Design of a screw
- 11-5 Design of a nut
- 11-6 Practical design of simple lifting machines (screw jack)
- 11-7 Compound screw
- 11-8 Differential screw
- 11-9 Ball screws
- Examples

**Chapter 12 : LEVERS**

- 12-1 Introduction
- 12-2 General procedure for design of levers
- 12-3 Hand lever
- 12-4 Foot lever
- 12-5 Cranked lever
- 12-6 Lever of a lever loaded safety valve
- 12-7 Rocker arm for Diesel engines (Straight arm)
- 12-8 Angular levers
- 12-9 Design of overhung cranks
- 12-10 Design of a crank pin (overhung crank)
- 12-11 Miscellaneous examples
- Examples

**Chapter 13 : BRACKETS**

- 13-1 Brackets
- 13-2 Hangers
- 13-3 Wall boxes
- 13-4 Design considerations
- Examples

**Chapter 14 : BELTS, PULLEYS AND CHAINDRIVES**

- 14-1 Introduction
- 14-2 Materials for belts
- 14-3 Design of belts
- 14-4 Design procedure for flat belts
- 14-5 V-belt drives
- 14-6 Design of V-flat drives
- 14-7 Pulleys : Materials and types
- 14-8 Cast iron pulleys
- 14-9 Design of cast iron pulleys
- 14-10 Steel pulleys
- 14-11 Wooden pulleys
- 14-12 Fast and loose pulleys
- 14-13 Speed cones
- 14-14 Short centre drive : Gravity idlers
- 14-15 Special tension adjusting belt drives
- 14-16 Chain drives : (Introduction)
- 14-17 Roller chains
- 14-18 Design of chain drives
- Examples

**Chapter 15 : FLYWHEELS**

- 15-1 Introduction
- 15-2 Determination of mass of a flywheel for a given coefficient of fluctuation of speed
- 15-3 Flywheel for punches and shears
- 15-4 Engine flywheels
- Examples

**Chapter 16 : GEARS**

- 16-1 Introduction
- 16-2 General characteristics
- 16-3 Spur gear terminology
- 16-4 Gear tooth forms
- 16-5 Accuracy of gears
- 16-6 Materials
- 16-7 Allowable stresses
- 16-8 Design considerations
- 16-9 Strength of gear teeth : Lewis equation
- 16-10 Dynamic tooth load
- 16-11 Design for wear
- 16-12 Gear wheel proportions
- 16-14 Racks
- 16-15 Introduction
- 16-16 Proportions for helical gears
- 16-17 Design of helical gear teeth
  - (a) Design for strength
  - (b) Design for dynamic load
  - (c) Design for wear
- 16-18 Herringbone gears
- 16-19 Rating of machine cut spur and helical gears
- Kilowatt power for strength, Kilowatt for wear
- 16-20 Introduction
- 16-21 Definitions
- 16-22 Strength of bevel gear teeth
- 16-23 Constructional details
- 16-24 Bearing loads
- 16-25 Introduction
- 16-26 Worm gear nomenclature
- 16-27 Strength of worm gear teeth
- 16-28 Bearing loads on the shafts
- Examples

**Chapter 17 : WELDED CONNECTIONS**

- 17-1 Introduction
- 17-2 Welding processes
- 17-3 Types of welded joints
- 17-4 Working stresses in welds
- 17-5 Strength of welds
- 17-6 Special cases of fillet welds
- 17-7 Eccentric loads on welded connections
- 17-8 Design procedure recommended by American Welding Society
- 17-9 Fillet welds under varying loads
- Examples

**Chapter 18 : DESIGN OF MISCELLANEOUS MACHINE PARTS I ENGINES AND BOILERS**

- 18-1 Design of flat plates
  - (a) Circular plate subjected to a uniformly distributed load of  $p$  and supported on the outside periphery
  - (b) Rectangular plate subjected to uniformly distributed load  $p$  and supported on the outside periphery
  - (c) Circular plate subjected to a uniformly distributed load  $p$  and clamped on the outside edge
 Project I Design of hydraulic press  
 Material selection, Design of a ram, Lower movable table  
 Upper table or Bridge piece, Packing for hydraulic ram
- 18-2 Design of a piston for I.C. Engines
- 18-3 Design of crossheads
  - Introduction, Wrist pin, Shoe, Guide, Crosshead bolts
  - Cap or keep plate
- 18-4 Design of connecting rods
  - Connecting rods and piston pins, Connecting rod type
  - Loads on connecting rods, Connecting rod length
  - Connecting rod sections, Materials, Calculations of connecting rods
- 18-5 Design of crankshafts
- 18-6 Design of a spring-loaded Hartnell governor
  - Introduction
  - (a) Spring design
  - (b) Design of a spindle
  - (c) Design of a cast steel body
  - (d) Design of a bell crank lever
- 18-7 Design of an eccentric, Design calculations
- 18-8 Compensating ring for a manhole
- 18-9 Design of safety valves for boilers
- 18-10 Design of a screw down steam stop valve
- 18-11 Design of cams (I.C. Engines)
- 18-12 Design of a valve gear for I.C. Engines
  - Materials, Valve Design, Design of a spring, Design of a lever or a rocker arm, Design of a push rod, Design of a camshaft
  - Rock arm, Fulcrum for a rocker arm, Roller end
- Examples

**Chapter 19 : DESIGN OF MISCELLANEOUS MACHINE PARTS II BRAKES AND CLUTCHES**

- (A) Hoisting equipments
- 19-1 Introduction
- 19-2 Design of hoisting chains and drums
- 19-3 Design of a hoisting rope
  - Values of  $m$  for various sections of curved Beams
- 19-6 Design of a crane hook
- 19-7 Introduction
- 19-8 Types of brakes
- 19-9 Design procedure for block brakes, Brake wheels, Brake shoe
  - Brake linings, Brake lever, Pull rods, Energy considerations in design of brakes
- 19-10 Band brakes : Introduction
- 19-11 Design procedure for band brakes
- 19-12 Introduction, Friction clutches, Cone clutch
- 19-13 Design procedure for friction clutches
- Examples

## Chapter 20 : DESIGN PROJECTS

### 20-1 Introduction

#### I Hand operated bench press

- |                           |                     |
|---------------------------|---------------------|
| (1) Lever                 | (6) Stand           |
| (2) Torque rod            | (7) Frame           |
| (3) Crank                 | (8) Sliding head    |
| (4) Toggle connecting rod | (9) Adjustable head |
| (5) Toggle bars           |                     |

#### Other considerations

#### Format for drawings

#### Surface finishes

#### Tolerances

#### Sketches and drawings

#### Reduction Gear

- (1) Selection of materials
- (2) Preliminary sketch
- (3) Gears
- (4) High speed shaft and bearings
- (5) Low-speed shaft bearings
- (6) Lubrication of gears and bearings
- (7) Housing
- (8) Hand operated bench press
- (1) Air cylinder
- (2) Compressed air receiver
- (3) Pneumatic arbor press
- (4) Bearing puller
- (5) Toggle jack
- (6) Bench vice
- (7) Governor bell crank lever
- (8) Bracket and bolts for tilting gear
- (9) Power shaft
- (10) Power shaft and a pulley
- (11) Back gear of a lathe

#### (12) Two speed gear box

#### (13) Single stage speed reducer

#### (14) Speed reducer

#### (15) Winch

#### (16) Pulley block

#### (17) Jib crane

#### (18) Cam

#### (19) Combination punch and shear

#### (20) Drill press

#### (21) Globe valve design

#### (22) Selection of materials

#### (23) Specific shapes for sections

#### APPENDIX I SI System

#### APPENDIX II Properties of Ferrous Materials

#### APPENDIX III Properties of Plastics

#### APPENDIX IV List of Indian Standards : "Testing of Materials"

#### APPENDIX V Indian Standards referred in the text

#### APPENDIX VI Preferred Numbers (Rounded values)

#### APPENDIX VII Deflection formulas for machine parts

#### APPENDIX VIII Metric threads

#### APPENDIX IX Common sizes of transmission shafts (Dimensions in mm)

#### APPENDIX X Properties of geometrical Sections

#### APPENDIX XI Imperial or Legal Standard Wire Gauge

#### APPENDIX XII Sizes of pulleys for flat and V-belts

#### APPENDIX XIII Width of flat cast iron and mild steel pulleys

#### APPENDIX XIV Service factors for belt drives

#### APPENDIX XV Load carrying capacity of V-belts

#### APPENDIX XVI Worm data

#### APPENDIX XVII Basic thicknesses of sheet and diameters of wire in millimetres